

Some Relations of Temperature Acclimation and Salinity to Thermal Tolerance of the Blue Crab, *Callinectes sapidus*

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ABSTRACT

The 48-hour median thermal tolerance limits of adult and juvenile blue crabs in relation to salinity and preceding acclimation temperature were estimated from experimental data. Crabs were less tolerant to temperature extremes at low salinity, and at both low (6.8‰) and high (34 ‰) salinities, the upper and lower tolerance limits increased as the acclimation temperature increased. Limits for adults and juveniles were similar.

INTRODUCTION

Mass mortalities of blue crabs have been attributed to extreme seasonal temperatures (Pearson, 1948) and to the discharge of heated water from power-generating plants (Washington Post, 1968). Sometimes it is difficult to ascertain if crab kills are the result of temperature changes because of the lack of knowledge of the temperature tolerance for various life history stages. This report presents the results of experiments designed to indicate the upper and lower lethal thermal limits of adult and juvenile blue crabs.

MATERIALS AND METHODS

Adult and juvenile blue crabs, obtained by trawl from Core Sound, North Carolina (range in salinity 20 to 30‰ and temperature 4 to 30 C), were acclimated to four temperatures (6, 14, 22, or 30 C) and two salinities (20% or 100% sea water). Crabs acclimated to 6 or 14 C were collected when mean monthly water temperatures ranged from 5 to 12 C (December 1967–March 1968); those acclimated to 22 or 30 C were collected when mean monthly water temperatures ranged from 12 to 22 C (October–November 1967 and April–May 1968). Adults were all females (mature), 130 mm or more in carapace width, and juveniles were males and females, 40–60 mm wide. Female blue crabs undergo a final molt at which they become sexually mature. This stage is easily recognizable because the abdomen changes shape from triangular to semicircular (the last stage of males cannot be determined from external appearance).

Because adult and juvenile blue crabs com-

monly occur in brackish portions of estuaries as well as in the ocean, tests were made in 20% and 100% sea water to determine any effect of these broad salinity differences on their thermal tolerance. Sea water (salinity 34‰) was obtained from the ocean, and 20% dilutions (6.8‰) were made with well water.

Crabs were individually isolated in polyethylene tubs containing 12 liters of water and acclimated for 21 days in two constant temperature rooms. Water temperatures, recorded continuously with thermographs, were maintained within ± 1 C. During acclimation, water in the tubs was changed once or twice and the animals were fed once.

Earlier experiments had indicated that a relatively long adaption to a new temperature was appropriate. Tests of mature females at both low and high temperatures (0, 38, or 39 C) showed that acclimation time affected survival; as the acclimation time (3, 7, 14, or 21 days) increased, survival time increased. Another decapod crustacean, the lobster, *Homarus americanus*, also has a slow gain in heat tolerance. McLeese (1956) found that acclimation was complete only after about 22 days.

In the present studies, adult and juvenile blue crabs at each acclimation temperature were exposed to test temperatures (at 2 C intervals) near the estimated upper and lower lethal limits of their thermal tolerance. The 48-hour median tolerance limits (temperatures at which 50% survive for 48 hours) were estimated by graphical interpolation (semilogarithmic paper). Crabs were considered dead when all appendages ceased to move.

TABLE 1.—Estimated median 48-hr thermal tolerance limits ($^{\circ}\text{C}$) of adult (mature female) and juvenile (40–60 mm wide) blue crabs in relation to salinity and preceding acclimation temperature

Per-centage sea water	Acclima-tion tempera-ture ($^{\circ}\text{C}$)	Adults		Juveniles	
		Upper	Lower	Upper	Lower
100	30	38.7	4.6	39.0	4.9
100	22	36.9	2.4	39.0	2.7
100	14	34.7	< 0.0 ¹	35.3	< 0.0 ¹
100	6	33.1	< 0.0 ¹	33.0	< 0.0 ¹
20	30	37.0	6.0	37.2	5.3
20	22	36.9	2.9	37.0	2.9
20	14	34.5	0.2	35.0	0.7
20	6	31.5	< 0.0 ¹	31.4	0.2

¹ 0.0 $^{\circ}\text{C}$ was the lowest temperature tested.

During the experiments and the acclimation period, blue crabs were held in subdued light, containers were covered to reduce evaporation, and water was aerated by compressed air passing through porous stones. Ten crabs were left at acclimation temperature for a control when others at that temperature were used for experimentation.

A high-temperature experiment (30 $^{\circ}\text{C}$ or higher) consisted of 10 blue crabs, each isolated in a polyethylene aquarium containing 6 liters of water. The aquaria were partially immersed in water baths at the bottom of six constant temperature cabinets. Compressed air was bubbled through the water to stir each bath.

Low temperature experiments (6 $^{\circ}\text{C}$ or lower) were carried out in a converted chest-type freezer, divided into compartments containing 75 liters of water. An experiment consisted of 10 adults divided between two compartments, or 10 juveniles in one compartment. Each compartment was lined with Fiberglas¹ and painted with nontoxic Inertol; water was recirculated by a pump. Crabs were not isolated because their inactivity when cold prevented cannibalism, and dead animals could be removed before deterioration fouled the water. In both the high- and low-temperature studies, Thermistemps and thermistor probes made by the Yellow Springs Instrument Com-

pany maintained the water in the test containers within ± 0.1 $^{\circ}\text{C}$.

THERMAL TOLERANCE OF BLUE CRABS

Adult and juvenile blue crabs were less tolerant to temperature extremes at the lower salinity, and at both low and high salinities the upper and lower tolerance limits increased as the acclimation temperature increased (Table 1). Almost all 48-hour TL_m of crabs in 20% sea water were 0.2 to 2.0 $^{\circ}\text{C}$ less than those of crabs in 100% sea water. Temperature tolerances at the two salinities may have been affected by differences in the amount of energy required to maintain the gradient between the blood and the external medium. Osmoregulation for a given species breaks down close to the lower or upper limits of the tolerated temperature range (Kinne, 1963), and the strain of maintaining a large gradient in low salinity adds to the strain on the metabolic activity of lethal or near lethal temperatures (Todd and Dehnell, 1960). Percentage of survival increased as the difference between test and acclimation temperatures decreased. Thermal tolerance limits between the highest and lowest acclimation temperatures differed from 5 to 6 $^{\circ}\text{C}$. Although the limits for adult and juvenile blue crabs were similar (usually within 0.5 $^{\circ}\text{C}$), juveniles generally were slightly more tolerant to heat and less tolerant to cold than adults. Control animals remained in good condition during the experiments.

A tolerance diagram (tolerance zone), derived by plotting lethal temperatures (48-hour TL_m) against acclimation temperatures, encloses an area that represents all thermal possibilities which adult (Figure 1) and juvenile (Figure 2) blue crabs can survive for a presumable indefinite period. A 45 $^{\circ}$ line indicates where the lethal and acclimation temperatures are the same. This method of displaying thermal tolerance was originally adopted for the goldfish, *Carassius auratus*, by Fry, Brett, and Clawson (1942).

The thermal tolerance of the blue crab exceeds that of the lobster and is similar to that of the most resistant species of fish. The area within each tolerance diagram was given a numerical value, with the area bounded by 1 $^{\circ}\text{C}$ (square degree) as the unit. For adult

¹ References to trade names in this publication do not imply endorsement.

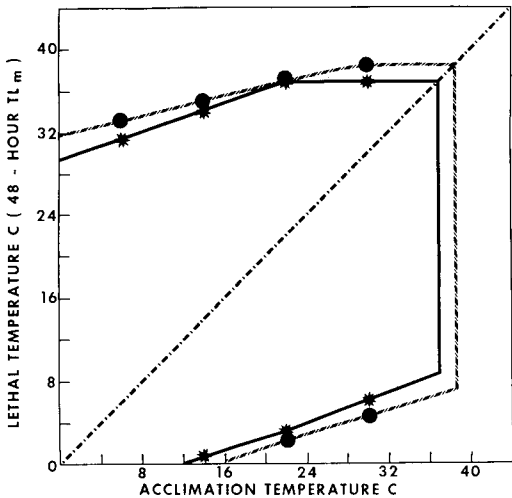


FIGURE 1.—The thermal tolerance of adult (mature female) blue crabs in 100% (broken line) and 20% (solid line) sea water. Lethal temperatures were plotted against acclimation temperatures as determined from experimental data.

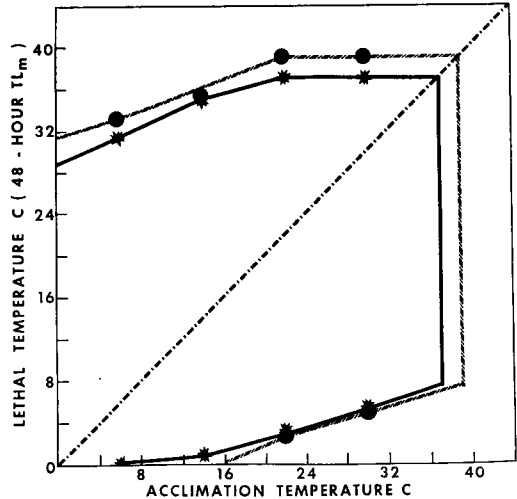


FIGURE 2.—The thermal tolerance of juvenile (40-60 mm wide) blue crabs in 100% (broken line) and 20% (solid line) sea water. Lethal temperatures were plotted against acclimation temperatures as determined from experimental data.

crabs, the thermal tolerances were 1,304 units in 100% sea water and 1,186 units in 20% sea water. The values for juveniles were slightly higher, 1,350 in 100% sea water and 1,204 in 20% sea water. The tolerance zone for the lobster has an area of 830 square degrees (McLeese, 1956). Values for 26 species of fish, given in the review by Brett (1956) and in the report by Hoff and Westman (1966), range from 450 square degrees for the pink salmon, *Oncorhynchus gorbusha*, to 1,220 square degrees for the goldfish.

Lethal or near lethal temperatures caused pronounced initial shock effects on blue crabs. Symptoms of heat shock were disturbances in equilibrium and erratic and rapid swimming that continued for a minute or more before subsiding. The symptom of cold shock was a continuous state of apparent paralysis, except for respiratory movement of mouth parts. Crabs recovered from "chill-coma" if the temperature was raised or if they were removed from the water. In a preliminary experiment, for example, 14 of 16 adult male blue crabs survived in good condition after a direct transfer from water at 1 C (held 4 days) to water at 20 C (held 10 days).

Male and female blue crabs probably have the same tolerance to temperature extremes.

Although sexual differences were not investigated in the present experiments, no consistent difference was evident in earlier studies of effects of abrupt changes in temperature or gradual changes to lethal high and low levels (Tagatz, 1968). The responses of males and females to heat were the same for the shore crabs, *Hemigrapsus nudus* and *H. oregonensis* (Todd and Dehnel, 1960), the sand crab, *Emerita talpoida* (Edwards and Irving, 1943), and the crayfish, *Orconectes rusticus* (Spoor, 1955).

Power plant discharge of heated waste water or unusually hot summers or cold winters cause temperatures that could be a threat to blue crabs. For example, some steam electric stations reportedly discharge water that ranges up to 46 C and causes significant increase in river temperatures as far as 5 miles downstream (Mihursky and Kennedy, 1967). Results of laboratory studies must be correlated with field observations to determine when any specific thermal condition in nature reaches lethal levels or becomes a limiting factor in blue crab distribution.

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